

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D. C. 20024

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SUBJECT: Rationale for Selection of a
50,000 Pound Propulsion Module
in an Integrated Manned Space
Flight Program - Case 710

DATE: July 7, 1969

FROM: A. E. Marks

ABSTRACT

An integrated manned space flight program for the next 10 years consisting of extensive operations in earth orbit and about the moon has been under study. A key element in this program is a 50,000 pound gross weight propulsion module which is used to inject large payloads into lunar orbit, land payloads on the lunar surface, serve as propulsion for LM type operations, and serve as an earth orbital tug. The economic environment as well as the technical approach have led to this stage size. The rationale behind the selection of this PM is presented herein.

(NASA-CR-106387) RATIONALE FOR SELECTION OF
A 50000 POUND PROPULSION MODULE IN AN
INTEGRATED MANNED SPACE FLIGHT PROGRAM
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MEMORANDUM FOR FILE

INTRODUCTION

An integrated manned space flight program for the next 10 years consisting of extensive operations in earth orbit and about the moon has been under study. In this program, a 50,000 pound gross weight propulsion module is developed and is used to inject large payloads into lunar orbits, land payloads on the lunar surface, serve as the propulsion for LM type operations, and serve as an earth orbital tug. The rationale behind the selection of a single propulsion module for these many varied applications follows.

DISCUSSION

PM-I and PM-II

Many studies have been conducted on new propulsion stage optimizations for lunar orbit and lunar surface payloads when the propulsion stage is used as a fourth stage on the Saturn V launch vehicle. These studies indicate a stage gross weight of from 110,000 to 140,000 pounds delivers the maximum payload to the lunar surface (Reference 1). This stage has been referred to as PM-I (Reference 2). When PM-I ($W_G = 140,000$ lbs) is placed on top of a Saturn V (127,000 lb TLI), a 55,000 pound lunar landed payload is achieved. This same configuration can place 120,000 pounds in lunar orbit.

Preliminary studies of a propulsion module to serve as a LM type system, or to return lunar surface payloads to earth, have shown the stage to be from 15,000 to 30,000 pounds gross weight. This stage has been referred to as PM-II (Reference 3). It will return 14,000 pounds to earth from the lunar surface, or serve as a lunar surface to orbit shuttle with a round trip payload capability of about 7,000 pounds.

These two PM's along with the Saturn V launch vehicle will provide the capability for extensive lunar and earth orbit operations. They also provide a foundation for steps toward the

planets. Technically, therefore, PM-I and PM-II provide a set of propulsion hardware common to all MSF needs (E.O., lunar, and planetary) and are desirable procurement items.

The major drawback of these PM's is that two new developments are needed, probably with two new propulsion systems. At the same time that these development programs would be undertaken, new starts would also be initiated for space station modules, an earth orbital space shuttle, and a nuclear shuttle. Considering the near term economic environment, it is extremely desirable to minimize any new starts, and perhaps proceed with a derivative type system such as a modified S-IVB in place of a PM-I.

S-IVC and PM-II

The modification of the S-IVB stage to replace PM-I was next investigated. This stage, referred to as S-IVC, consists of suiting the S-IVB for longer lifetime (since it must be carried past TLI) and making a landing stage out of it. This necessitates the addition of high performance insulation (HPI) around the tanks, separation of the tanks from the common bulkhead arrangement that now exists, the addition of landing legs, and the replacement of the J-2 engine with derivative RL-10 engines. These modifications would in essence be equivalent to a new start in cost and time and would yield only moderate performance as a fourth stage on Saturn V--40,000 pound lunar surface payload and 100,000 pound lunar orbit payload. The S-IVB modified to be a lunar lander has been studied (Reference 4), and total propellant losses (boiloff, residuals, etc.) amounted to about 10,000 pounds. This same propellant loss was used to determine S-IVC performance.

The PM-II stage would still be used in addition to S-IVC for the missions previously discussed. Its configuration is maintained as is. Therefore, two types of propulsion systems may again be needed.

S-IVB' and PM-II

Another method of accomplishing the lunar orbiting and lander missions is to examine minimum modifications to the S-IVB and to use a resized PM-II as the landing vehicle. This would constitute a five stage Saturn V with the fourth stage being a modified S-IVB stage, and the fifth stage being PM-II. The modified S-IVB stage, referred to as S-IVB', would be required past TLI and would thus require the addition of HPI to increase storability of the cryogenics, and the use of a J-2S engine for uprated performance. The PM-II stage size needed for landing on the lunar surface would be about 35,000 pounds gross weight. The resulting performance of this configuration would be 38,000 pounds landed on the lunar

surface (five stage Saturn V) or about 35,000 pounds (four stage Saturn V where S-IVB' replaces a S-IVB). A four stage configuration without the PM-II, i.e., an S-IVB' on top of an S-IVB, will place about 88,000 pounds in lunar orbit. These performance figures suggest the possibility of building one propulsion stage that could perform all the PM-I and PM-II functions without a major compromise in performance of any of the missions, since the payload to the lunar surface is not significantly increased by using a large S-IVB type stage rather than PM-II.

50,000 Pound Propulsion Module

The performance of a single propulsion module, called PM, is evaluated as a function of PM gross weight for lunar lander and orbiter missions. The stage size is optimized for the lander mission, since the orbiter mission payload is found to be almost completely insensitive to PM gross weights of from 40,000 to 100,000 pounds. The landed payload is shown in Figure 1 as a function of PM gross weight. As the PM gross weight and payload vary, the effect of the necessity for carrying the S-IVB past TLI is clearly shown. It would therefore be desirable to have a PM plus payload combination equal to or exceeding the TLI capability of the launch vehicle such that the S-IVB is not required to burn past TLI. This would eliminate the need for any extensive modifications to the S-IVB and save the 10,000 pound propellant loss due mainly to boil-off during the lunar transfer time.

The use of a 68,000 pound PM as a fourth stage on a Saturn V will land about 52,000 pounds on the lunar surface or place about 100,000 pounds in lunar orbit. This assumes that the PM is designed such that propellant losses due to boiloff are a minimum. This single stage has the advantage over the others mentioned in that the S-IVB need not be modified, RL-10 derivative engines are used eliminating the need for a completely new engine development, and only one new stage is developed.

The major difficulty with the 68,000 pound PM is programmatic. The flights to lunar orbit will have a payload capability of about 100,000 pounds. One mission would have a payload consisting of a space station module (approximately 50,000 lbs) and a PM. This payload, however, would exceed the capability of the Saturn V plus PM to lunar orbit. Another mission would have a payload of two PM's which would also exceed the capability of the launch system.

The possibility of a 50,000 pound PM was then investigated, and the lunar orbit payload was found to remain at about 100,000 pounds. The contemplated mission payloads then fell within the capability of the launch system. The lunar landed payload, however,

suffered greatly using a four stage Saturn V since the S-IVB was now required to fire after TLI. A second PM was then added making a five stage Saturn V and the lunar landed payload was 52,000 pounds with the S-IVB not required past TLI.

A schematic of a 50,000 pound gross weight PM is shown in Figure 2, while Figure 3 gives some of the physical characteristics of the stage and shows its performance for various applications--as an earth to lunar injection stage and lander, as a space tug in earth orbit, and as a lunar surface to orbit shuttle. As a lunar surface to orbit shuttle, the performance shown in Figure 3 is for round trips with the left side being the down payload and the right side being the corresponding up payload. As an example, mission 2 consists of bringing down 38,000 pounds to the lunar surface and returning to orbit empty. Mission 3 lands 52,000 pounds and is expended (does not return to orbit); hence no mission 3 on the right side. The versatility of this stage is obvious, consequently 50,000 pounds was selected as the gross weight of the propulsion module.

CONCLUSIONS

The development of a single 50,000 pound PM to perform PM-I and PM-II missions is quite feasible. This single stage represents a compromise to the two new stage developments in as much as performance is somewhat lower, but the programmatic and financial aspects of a single stage make it highly desirable. The modification of the S-IVB stage, either as a lander or an injection stage, is not competitive to the single PM in either performance or cost. A significant integrated MSF program can be accomplished with this stage and an associated earth orbital shuttle until such time as the economic environment changes to allow a more technically oriented approach toward manned space flight.

A. E. Marks

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A. E. Marks

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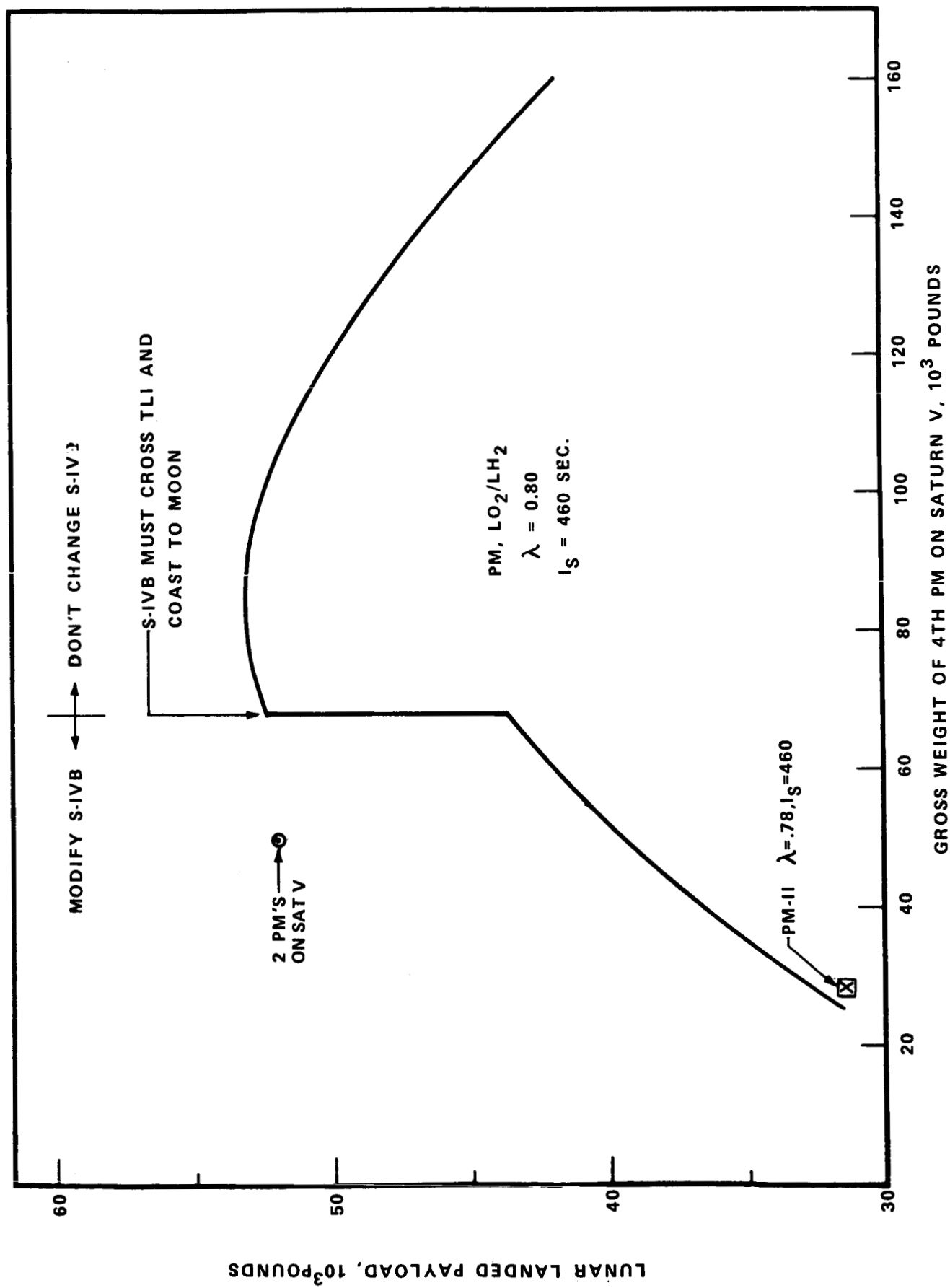
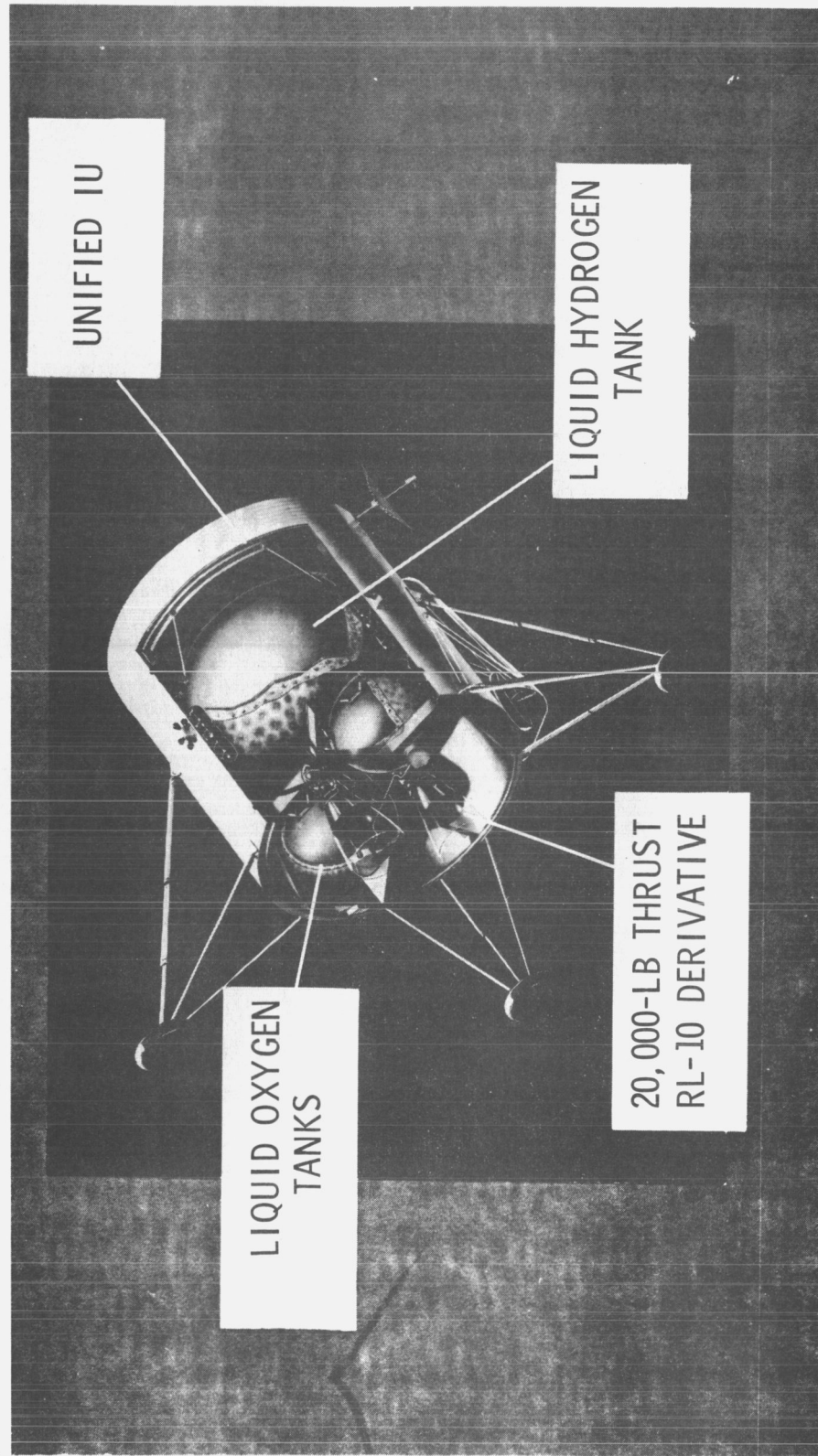


FIGURE 1 PROPULSION MODULE PERFORMANCE AS A LUNAR LANDER

FIGURE 2

SPACE TUG PROPULSION MODULE
(TYPICAL)



REPT. LMSC-T-28-68-4

FIGURE 3

SPACE TUG PROPULSION MODULE

PHYSICAL CHARACTERISTICS:

GROSS WEIGHT - 50,000 LBS.
 PROPELLANTS - LO_2/LH_2
 MASS FRACTION - 0.80
 SPECIFIC IMPULSE - 460 SEC.

LENGTH - 25 FT.
 DIAMETER - 22 FT.
 ENGINE - 4 RL-10 DERIVATIVES

STAGE PERFORMANCE

4th STAGE ON SAT. VC
 PAYLOAD TO L. O. = 100,000 LBS

4th & 5th STAGE ON SAT VC
 PAYLOAD TO LUNAR SURFACE 52,000 LB.

SPACE TUG

$\pm 22^\circ$ IN L. E. O. }
 $\pm 60^\circ$ IN SYNCH. } 5,000 LB.

LUNAR MISSION ROUND TRIPS (REUSABLE)

PAYLOAD FROM LUNAR ORBIT TO LUNAR SURFACE	PAYLOAD FROM LUNAR SURFACE TO LUNAR ORBIT
15,000	15,000
38,000	-0-
52,000 (EXPENDED)	
27,000 (20,000 LB. DISCRETIONARY ON A 3 MAN 28 DAY SORTIE-LMB)	7,000 (SPACE CREW CAPSULE)
7,000 LB (SPACE CREW CAPSULE)	44° PLANE CHANGE ABILITY WITH 7,000 LB SPACE CREW CAPSULE (NO DISCRETIONARY PL)

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